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Compression Of Martian Atmosphere For Production Of Oxygen

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Abstract

This research program deals with the compression of  $\text{CO}_2$  from the Martian atmosphere for production of  $\text{O}_2$  via an electrochemical cell. Design specifications call for an oxygen production rate of 10 kg. per day and for compression of 50 times that mass of  $\text{CO}_2$ . Those specifications require a compression rate of over 770 cfm at standard Martian temperature and pressure (SMTP). Much of the  $\text{CO}_2$  being compressed represents waste, unless it can be recycled. Recycle can reduce the volume of gas that must be compressed to 40 cfm at SMTP. That volume reduction represents significant mass savings in the compressor, heating equipment, filters and energy source. Successful recycle of the gas requires separation of CO (produced in the electrochemical cell) from  $\text{CO}_2$ ,  $\text{N}_2$ , and Ar found in the Martian Atmosphere. That aspect has been the focus of our work during the first year.

Background

The Space Engineering Research Center (SERC) at the University of Arizona is in the progress of designing and building a prototype system for production of  $\text{O}_2$  from  $\text{CO}_2$ . While SERC is currently addressing conditions typical of the Martian atmosphere, the technology being developed is applicable wherever  $\text{CO}_2$  is produced and can be used as a raw material.

Recycle of the gas leaving the electrochemical cell has a distinct advantage of reducing the volume of the Martian atmosphere that must be compressed. Successful recycle, however, requires separation of the CO produced in the cell from the remainder of the compressed atmosphere. Carbon dioxide and carbon monoxide are not easily separated as both have the same approximate kinetic diameters since both molecules are linear. That fact precludes the use of zeolites for the separation of CO from  $\text{CO}_2$ . Polymeric membranes are used to separate  $\text{CO}_2$  from CO. Since the gas stream under consideration consists primarily of  $\text{CO}_2$  an extensive membrane surface area would be required. In addition the membranes are susceptible to failure at elevated temperatures.

Cooling the gas leaving the electrochemical cell to a temperature where polymeric membranes could be used to separate CO<sub>2</sub> from CO could result in carbon deposition. That deposition, if not controlled, could lead to failure of the entire system.

Thermodynamic analysis of the exit gas, as proposed, has revealed that carbon deposition is possible at temperatures below 500 °C. The reaction involved,



is referred to as the disproportionation reaction. At temperatures below 600 °C the reaction is sluggish, but is known to be catalyzed by ferrous metals[1-4]. That knowledge can be used in conjunction with reaction 1 to remove CO and thereby provide for recycle of CO<sub>2</sub>.

### Approach

The basic approach to the experimental program involves testing the effectiveness of various catalyst for disproportionation of CO from a gas stream consisting primarily of CO<sub>2</sub>. To accomplish that task an apparatus consisting of a tube furnace, controller, gas chromatography and gas delivery system has been assembled as shown in Figure 1.

An experiment is initiated by placing the catalyst in the tube furnace and purging the entire system with an inert gas. After the desired temperature has been obtained in the furnace, a CO<sub>2</sub>-CO-N<sub>2</sub> gas mixture is allowed to contact the catalyst. Both the inlet gas stream to the furnace and exit gas stream from the furnace are sampled and the resulting specimens analyzed using a gas chromatography. The resulting data is used to determine the effectiveness of the catalyst in the disproportionation of CO. This technique is being used to test a number of catalysts.

Those catalysts that prove effective in the disproportionation of CO will under go repeated tests in order to evaluate long term effects. That testing will include burnout of the carbon using CO<sub>2</sub> at temperatures above 700 °C. Following burnout the catalyst will, again, be exposed to the CO<sub>2</sub>-CO-N<sub>2</sub> atmosphere for carbon deposition. The effectiveness of the catalysts will be plotted as a function of the number of cycles. It is anticipated that the effectiveness of the catalyst will depend in large part on its surface morphology and how it changes with repeated use. Scanning electron microscopy will be used to evaluate any changes.

### Experimental Results

A number of catalytic carriers have been selected based on their surface area and pore size distribution. All of the carriers are ceramic, and as such are not expected to be effective in enhancing the disproportionation reaction. A typical result for Celite which has a surface area of

67 m<sup>2</sup>/g and a mean pore diameter of 0.19  $\mu$ m is shown in Figure 2. It is necessary to conduct these experiment to achieve a minimum base line for comparison purposes. In order to improve the performance of the carriers we are investigating methods whereby the surface of the carrier can be partially coated with an active metal. The catalytic carrier serves to provide a stable structure with a high surface area over which micro droplets of metal are distributed. Those droplets will coalesce. The rate at which coalescence occurs will depend on both the temperature and duration at which the catalyst is exposed to that temperature. Without the carrier both surface diffusion and vapor phase transport could significantly reduce the surface area of metal particles.

#### Student Participation

Mr. Peter E. Nolan, a U. S. citizen, is working on this project. Peter has an Applied Physics Degree from the University of California at San Diego. After completing his undergraduate degree he served several years as an officer in the U. S. Navy. Peter joined our group in July, and since then has been responsible for construction and testing of the experimental apparatus. He is currently in our M. S. degree program and has applied to NASA for admission for astronaut training.

#### References

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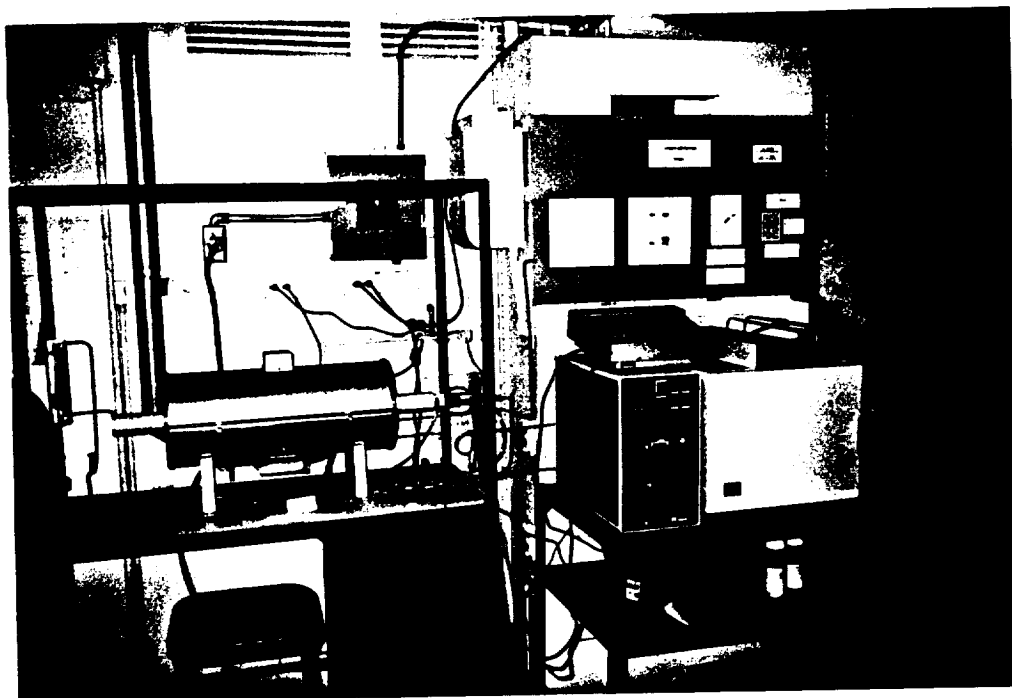


Figure 1 - Experimental Apparatus

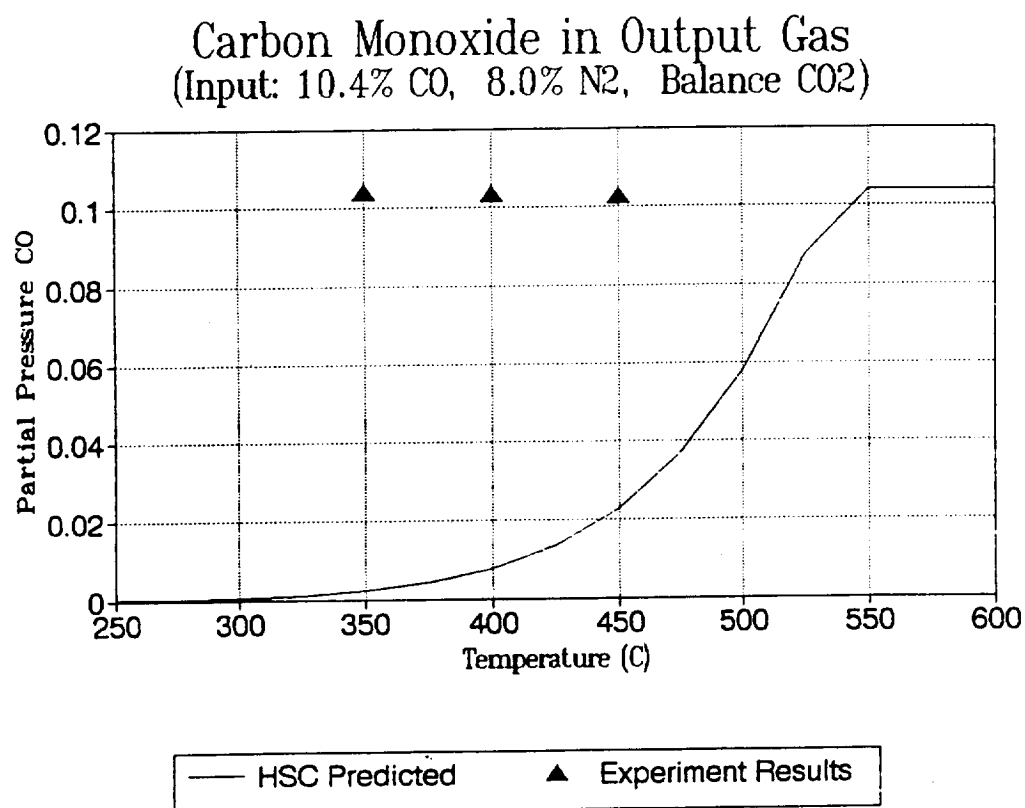


Figure 2 - Experimental Results With Catalytic Carrier, Celite

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### **C. REDUCTION OF CARBONACEOUS MATERIALS**